A Market-Based Approach to Workflow Automation

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Abstract

We propose a market-based approach to workflow problems in which human and computer agents bid for tasks and resources in an open market or auction, and demonstrate its applicability to a small business loan application process. Workflow problems generally require the coordination of many workers, machines and computers. Markets provide a natural mechanism for scheduling tasks and allocating resources. Markets serve many functions: bidding provides asynchronous communication between different agents, allowing them to communicate their capabilities, utilities, and availabilities while hiding irrelevent details of the individual work processes. Auctions optimize the allocation of tasks and resources and determine transfer prices. By properly structuring the auction, incentive compatibility can be assured, so that agents are rewarded for being productive and for giving truthful and accurate assessments of their utilities. The decentralized structure of a market also facilitates longer term learning by individual agents. Optimization theory and operations research provide some insight into the limitations of distributed systems such as markets and suggest cases where the decentralized market must be supplemented by a central controller which uses market intervention to assure stability and global optimality.

Market-based systems - introduction

Increasingly, work is a collaborative effort between multiple people and computers. In such complex undertakings, there are typically many data repositories and many decision makers, each of whom must communicate and coordinate decisions with a variety of human and computer agents. We are developing an agent and market-based approach for the control of complex service delivery systems such as those arising in workflow, purchasing, and transportation. Such systems are characterized both by the need for human/machine communication and by the complexity of the processes and their divergence; i.e., the ability of the service provider(s) to create alternative paths through the process by their actions. In addition, the criteria of performance of these systems are often multi-dimensional, incorporating measures such as service time, adherence to promised due dates, costs, and service quality. The goal of this research is to extend agent and market-based control schemes to create a theory for the design and implementation of adaptive intelligent workflow systems for the control of such processes. In these schemes, control is decentralized to various human and computer (e.g., databases, schedulers, models) agents that bid for the opportunity to work on various service delivery tasks.

There has been substantial work in academia in recent years on intelligent agents (Maes 1993), and in

bids will be awarded. If they assess their chances of making money as worth the effort, agents respond to RFBs with bids. Bids contain a description of the tasks to be performed and a function relating price to be paid as a function of both the time the raw material for the tasks is supplied and the time that all tasks are completed. Many simplified versions of this function can be used, e.g., the information needed to begin the task may be available at bid time, and payment before a due date may not be a function of time.

The goal of the scheduling is to assign tasks to agents in a fashion which minimizes the total price paid by the originating agents. In the context of the market-based economy, this can be viewed as a two level optimization. At the higher, master, level, the price offered to have jobs completed may be adjusted, as may the length of time that agents wait for bids or guarantee to fulfill bids that have been made. Agents may also be removed or re-deployed if they become bankrupt - they persist in failing to create value. At the lower level, each agent does a local optimization in determining its schedule in order to maximize its income.

Establishing internal transfer prices for work done has the added advantage that companies can use this information to help make the "make/buy" decision: oil refineries can often choose between making a given blend of oil or buying it on the spot market, and service industries can subcontract out work. Indeed, as computer coordination technology improves, companies are downsizing and subcontracting more work.

Research program.

A market-based scheduling system is being developed and used to address a series of theoretical and practical questions concerning the structure and limitations of the proposed approach. Specifically, simplified adaptive work flow systems are being studied to address questions of stability, convergence and optimality. Key questions involve selecting the auction procedure and deciding what centralized operations are required to assure good performance. Analysis methods include optimization, control theory, and game theory (e.g., principal/agent theory).

Key system design issues include: Defining the language for communicating and resolving bids, selecting the internal representations used by the computer agents, selecting statistical process control models to ascertain when the process is out of control (e.g., oscillating) and thus, market intervention is necessary, and developing evolutionary optimization algorithms to adaptively improve the performance of the system.

Structured simulations are being used to test how well the theoretical results apply to more realistic systems. In particular, an adaptive workflow control system has been developed in C++ and Lotus Notes and its performance is being tested on a model of a small business loan application process.

Application to small business loan processing

A natural setting for studying market-based approaches to workflow automation is in financial services. Financial services are the largest single consumer of information technology in the economy, investing $38.7 billion dollars in 1991 (National Research Council 1994; p. 2). Banks are actively seeking the type of technology and operations management knowledge outlined herein since a major success factor as stated by retail banking leaders includes flexibility and responsiveness in operations (Roth and van der

Conclusions

Workflow systems for processes such as credit approval and manufacturing job shops need to combine flexibility with scheduling and optimization. Markets offer an efficient mechanism for such workflow scheduling. They are naturally decentralized, distributed and flexible, and they support the inclusion of humans in the scheduling process by allowing asynchronous communication, encouraging specification of utilities, and being incentive compatible. We have taking the first steps toward establishing a market-based workflow system, and are testing in on a small business loan approval process.

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